

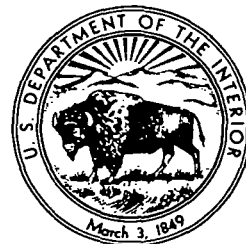
# Geology and Ore Deposits of the Picher Field Oklahoma and Kansas

By EDWIN T. McKNIGHT and RICHARD P. FISCHER

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*A discussion of one of the world's  
great mining fields—its geology,  
mining history, and potential*



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royalties were all too commonly pyramided by this method to an excessive degree, which interfered with development of the field except in periods of high mineral prices. Most leases have been for comparatively short term and have usually required active operation to avoid forfeiture.

### HISTORY OF MINING

Ore was first discovered in 1901 about  $1\frac{1}{2}$  miles northeast of Lincolnville, Okla., by churn drilling on Abrams land (SE $\frac{1}{4}$  sec. 30, T. 29 N., R. 24 E.) and on Julia Whitebird land (SW $\frac{1}{4}$ SW $\frac{1}{4}$  sec. 29). In mid-1902, an exploratory shaft was sunk to ore at a depth of about 50 feet on one of the Abrams drill holes. The vigorous exploration that was stimulated by this initial discovery soon found ore on adjacent tracts. Small mills were built, and the first recorded output of sulfide concentrates from the Lincolnville area was made in 1904. Churn drilling of the area showed that the main deposits were in "blanket ground" at a depth of only 50-150 feet. In the 3 years ending with 1906, the production from the several shafts amounted to 6,545 tons of zinc sulfide concentrates and 1,385 tons of lead sulfide concentrates, at a total value of nearly \$350,000. The Lincolnville deposits were comparatively short lived, however, with peak production in 1909. A few deposits here cropped out at the surface, and zinc silicate that had formed in the soil had, before discovery of the sulfides, been plowed up in a field and cast aside in ignorance of its identity. Much of this ore was later shipped when its true nature was recognized.

Zinc sulfide was found in cuttings from the town well at Quapaw, 2 miles northwest of Lincolnville, in or just before 1907. The next discoveries were made in another group of fringe deposits at the south side of the field, at what is now Commerce (formerly Hattenville). Following a churn-drilling campaign started here in 1905 by Robinson & Coleman (precursor of Commerce Mining & Royalty Co.), ore was reached by the first shaft in 1907. In the following year the production from this and several other shafts that had been put down nearby was more than double that in the Lincolnville area. In the early days, the Commerce mines were handicapped by a high royalty rate, by a large volume of water that made pumping costs excessive, by high concentration of hydrogen sulfide in the ground, and by excessive tar in the ores, which complicated the milling problems and led to penalties in marketing the concentrates. Yet in spite of these handicaps, the ore was so much richer in comparison to other Tri-State mines that development of the area progressed rapidly. The early

mines were comparatively shallow, at depths of 90-130 feet; but as the ore was followed northwestward in succeeding years, the depth increased to as much as 250 feet by 1911, and eventually to 385 feet. As the field was extended, the water and gas handicaps were greatly reduced through lowering of their initial head, and the amount of tar in the ore deposits decreased.

The exploration stimulated by the richness of the ores at Commerce and by the recognition of a northeasterly trend in some of these ore runs (see pl. 1) finally led to the discovery of the main part of the field in 1912. Although no mines were opened in the heart of the field that year, the drilling was extensive as far as the Kansas State line, and at least one important discovery was made in Kansas, on the Scott Jarrett land a few thousand feet north of the State line just west of the Blue Mound. Beginning in the following year, shafts were sunk and mills were built at an accelerating rate in the new part of the field. The first new mines were in the south, adjacent to the Commerce area.

A very important drilling discovery was made in the summer of 1914. The Picher Lead Co. had been exploring a large acreage between Commerce and the Kansas line, with results so discouraging it was decided to abandon the project. In attempting to get back to Joplin, a drill rig belonging to Dick Blosser got mired in a shallow prairie slough between Tar and Lytle Creeks, less than a mile south of the Kansas line. As there was going to be some delay before the rig could be extricated from the mud, and as the spot was within the large tract under lease to the company, the driller sought and was granted permission to put down a hole in order to retrieve some of the expense that had befallen him as a result of the mishap. On August 2 he struck ore of such richness as to change the decision of the company about abandoning the field (Eng. Mining Jour., 1943). Additional holes proved a rich ore body on the Crawfish land, on which this hole was drilled, and on several adjacent allotments of Indian land. By late 1915 the producing area of the field had expanded to include the Whitebird mine on one of these adjacent tracts, and the Crawfish, Bingham, and Netta mines began production shortly thereafter.

At the end of 1917 the Oklahoma part of the field was fairly well defined by producing mines, the Kansas deposits were largely outlined by new shafts or drill holes, and in that year the initial output from the Kansas side of the State line had been made from the Barr, Blue Mound, and Blue Diamond mines. Table 4 shows that the production of zinc concentrates virtually doubled in 1916 over the preceding year, tripled in 1917, doubled in 1918, and increased at a large, though some-



what less spectacular, rate in the next 2 years; the increase was from 28,000 tons in 1915 to 502,000 tons in 1920.

This phenomenal expansion was made possible by the multitude of mining companies operating in the field, each acting independently of the others in a favorable market stimulated by World War I. The landowners could award leases freely to any company that they might choose. Because of the shallowness of the deposits, the relative ease with which they could be mined and milled, and the wide technical experience gained from earlier operations in adjacent subdistricts of the Tri-State region, many relatively small but efficient mining companies were organized that required only moderate capital for operation on a 40-acre tract; the number of such tracts available was large. Hence, the average mining company tended to be small to moderate in the size of its operations. However, several major well-known companies or their subsidiaries entered the field on a modest scale. The St. Louis Smelting & Refining Co. (National Lead Co.), U.S. Smelting, Refining & Mining Co., Miami Zinc Syndicate (Butte & Superior Mining Co.), and Chanute Spelter Co. (American Metals Co.) became active in 1916, the United Zinc Smelting Corp. in 1917, and Federal Mining & Smelting Co. in 1918. Some of these abandoned the field after a short period, others remained as relatively small operators, and still others, particularly the St. Louis Smelting & Refining Co. and the Federal Mining & Smelting Co., expanded their operations later to sizable proportions. It was estimated in 1918 that there were 230 mills built or under construction in the Oklahoma part of the field, many having come secondhand from the older Missouri fields; and there were at least 20 more in the newer part of the field in Kansas. These figures can be taken as a rough measure of the number of individual operations. Some companies carried on multiple operations in areas that were not contiguous. Each operation ran the complete gamut from development drilling to the milling and marketing of concentrates, controlled only by the economics of mining within its pertinent unit. With the profits so widely dispersed, each unit tended to produce at maximum rate and efficiency. But to avoid forfeiture of leases that commonly obligated the operators to a stated minimum rate of output, there was also some forced production in excess of economic production, particularly after the price of zinc fell in early 1917. A large turnover in operating companies from year to year was inevitable as leases changed hands or were subdivided or regrouped under different operations, and the names of mines were constantly changing in a most bewildering fashion. As ore bodies commonly ex-

tend from one tract to the next, the concept of what constitutes a "mine" in the field is rather artificial.

The landownership pattern and leasing system prevented any domination of the field by a single company or small group of companies. Nevertheless, there were two mining companies that, in the initial development of the field, stood out above the others in the size and diversity of their operations. A parent company of the Commerce Mining & Royalty Co., with capital raised largely in Miami, the county seat of Ottawa County, had originally discovered and opened up the south edge of the field at Commerce (Hattenville). As the field grew, this company acquired control of a large mineral acreage, particularly through the western part of the field in Oklahoma, but also at one time or other, in scattered tracts throughout the field in both States. Initial activity, under the earlier name of Miami Royalty Co., was largely devoted to subleasing of its leased lands to other operators at an increased royalty rate over that paid on the first lease to the land owners, but the company soon became interested in active mining. The other leading operator, Picher Lead Co., originally of Joplin, which later merged with Eagle White Lead Co. to become the Eagle Picher Lead Co., leased 3,000 acres in Oklahoma, mainly just south of the Kansas line but with smaller segments north and northeast of Commerce. Exploration was started in 1913. The town of Picher grew on this leased land as a result of the rich discoveries and mine development. This company also subleased many of its properties to other companies from time to time.

Several other companies also stand out in the early history of the field. An association of Joplin and Miami men, under the company name of Church & Mabon, had taken part in the early development at the north end of the Commerce area, starting about 1910. When the main part of the field was discovered, this association gained control of a large acreage in the southern part of the field about 1½ miles southeast of Cardin, and under the new name of Welch Mining Co., proceeded to develop the ground. By mid-1917 the output of this company rivaled that of the two leading companies. At that time the leases on 200 acres southeast of Cardin were sold to the Skelton Lead and Zinc Co., which maintained the group of properties intact for many years during which the Skelton company was usually among the leading producers of the field.

The Golden Rod Mining & Smelting Co. in 1917 purchased several adjacent developed properties totaling 320 acres in the heart of the field, east of Cardin, including the old McConnell mine (now part of Kenoyer mine), which was the first property developed



in the Cardin area, as it had a shaft to ore in 1913. The company name was carried over from the Golden Rod Mining Co., an entirely different association, which in the preceding year had developed one of the purchased properties. In succeeding years, the output from the several mills on this block of land was an important segment of the total production from the field. The company later merged with a lead-products manufacturing concern to become the Evans-Wallower Lead Co., and later, Evans Wallower Zinc, Inc. The block near Cardin remained virtually intact until late in the history of the field, though additional holdings of the original company and its successors in other parts of the Picher field were bought and sold independently of the Cardin block.

The Underwriters Land Co., one of the oldest and largest operators in the old Joplin area, and the Admiralty Zinc Co. became active in the Picher field in 1915, and the latter company made its initial production in that year. In the following year the O. M. Bilharz Mining Co. entered the field with the purchase of two developed properties (Bluebird and Shorthorn). During the period of rapid development and accelerating production from 1916 to 1920 inclusive, these three companies also ranked among the 10 leading producers. The Admiralty and Bilharz companies remained steady producers for many years, although their relative importance was not so great later as during the early years. The Underwriters Land Co. lost its identity in the mid-1920's through a merger that produced an even more prominent successor company.

Because of the flatness of the terrain, transportation lines were no problem in the development of the field. The Oklahoma, Kansas, & Missouri Interurban Railway, later called the Northeast Oklahoma Railroad Co., which in 1908 had been constructed over the 4 miles from the main line of the St. Louis & San Francisco at Miami to Hattenville, was extended in 1916 to the new mining towns of Cardin and Picher, and spurs were extended to various mines as fast as developments warranted them. Another railway, the Miami Mineral Belt, was laid in 1917 from the main line at Quapaw to Cardin and Picher, and was extended in the next few years to Baxter Springs and also to much of the mining area. A third line, the Southwest Missouri Electric Railway, was completed in 1918 from Galena, Kans., to Picher.

Despite slumps in metal price that began in 1916 and were accentuated in the latter half of 1917, development of the field was carried forward largely on its own momentum and coincident with generally falling prices until a temporary peak of production was reached in 1920. Because of the number and type of operations,

the adverse economic conditions during this period merely slowed the rate of increase in production without reversing its direction. Both zinc and lead prices reached lows in 1921, and the overall production of the field was at last curtailed drastically in that year. Many good mines were shut down for months, or even more than a year.

The setback was only temporary. With recovery in price during the next few years, the alltime peak of production was reached in 1925 when 749,000 tons of zinc concentrates and 130,000 tons of lead concentrates, equivalent to 387,000 tons of recoverable zinc and 101,000 tons of recoverable lead, were produced. The production had become delicately adjusted to price, which reached a cyclic peak for both metals in this year. Figure 20 shows the relation for zinc. With the increased economic competition in a market that had to adjust production to demand, there was an increasing tendency during the 1920's for the larger and more efficient mining companies to expand holdings and operations gradually at the expense of the small operators. Typically, the increased holdings were scattered in separated tracts throughout the field; many were held only temporarily and then abandoned for others.

In addition to the companies previously mentioned that had assumed an early lead in the development of the field, the Federal Mining & Smelting Co. increased its holdings, largely through a single deal in 1924, to where it ranked among the major producers, and was, indeed, the leading producer in the three years 1924-26. The St. Louis Smelting & Refining Co. also increased its operations in the early 1920's, to rate among the top producers, though its output was much lower in the latter half of the decade while it was developing large reserves near Baxter Springs. Other companies that commonly rated among the top 10 producers at different times in this decade were the Vinegar Hill Zinc Co. and the Century Zinc Co. (both subsidiaries of Youngstown Sheet & Tube Co., though the Vinegar Hill Co. had other affiliations before 1923), Consolidated Lead & Zinc Co., Anna Beaver Mining Co., Interstate Zinc & Lead Co., and New Chicago Mines Corp. Several expansions were effected through merging of smaller companies, the most notable being that in 1926 between the Underwriters Land Co. and the Consolidated Lead & Zinc Co., retaining the latter's name. The new company, which was a subsidiary of Eagle Picher Lead Co., rated, along with its parent company, among the top five producers of the field for the next few years. The Interstate Zinc & Lead Co. also attained its prominence in the same year through a merger of four earlier companies; its richest property was the Woodchuck mine.





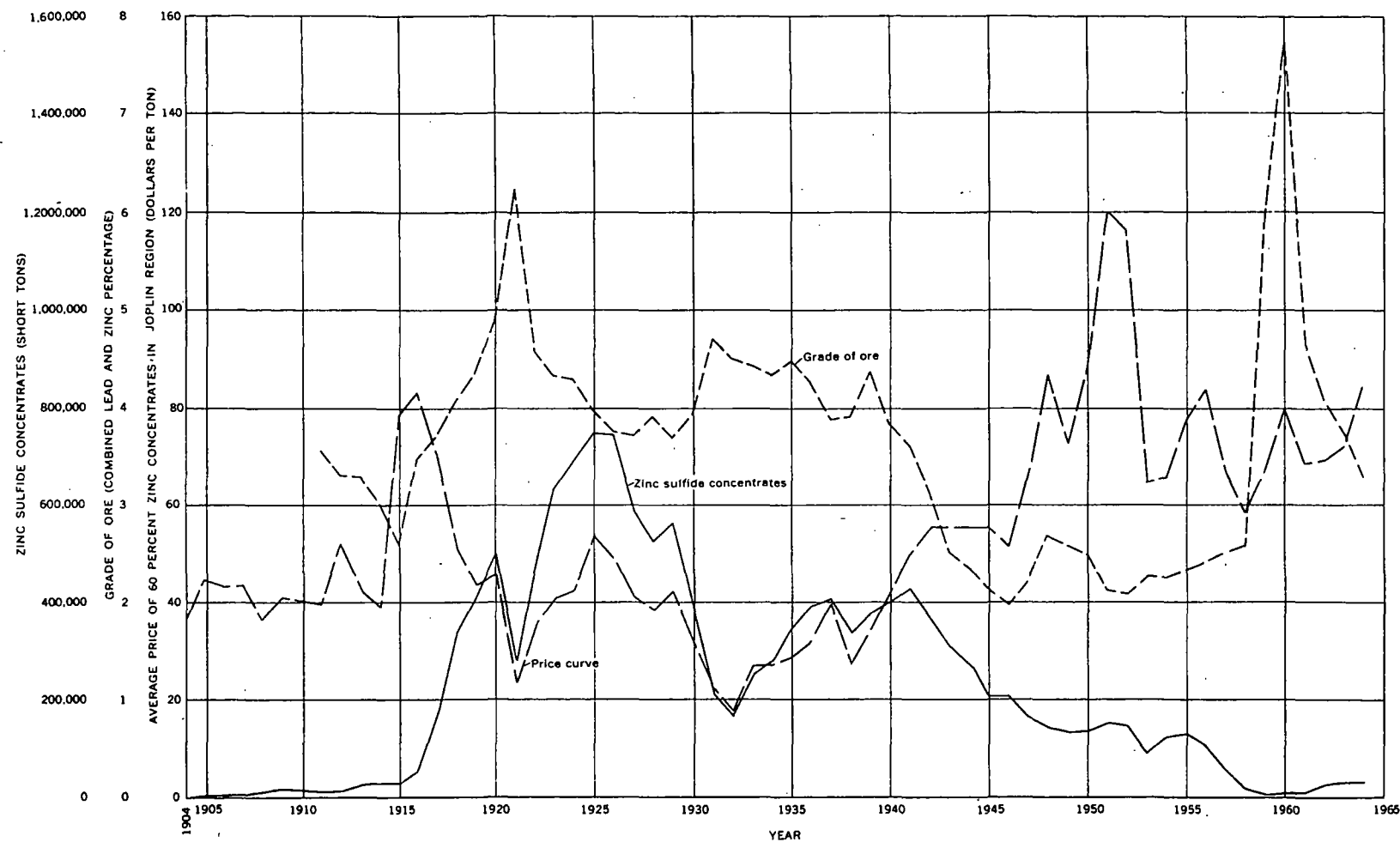


FIGURE 20.—Graph showing zinc sulfide concentrates production of Picher field and grade of ore in relation to selling price of standard 60 percent zinc concentrates. (The price paid to producers from 1942-47 was augmented over that shown in this chart by premium payments under the Premium Price Plan.) Average price from "Metal Statistics 1965," (American Metal Market, 1965, p. 504).



The Kansas Exploration Co., a subsidiary of St. Joseph Lead Co., began exploring a large tract in Kansas in 1921. The project failed to discover any extension of the field but resulted in opening a mine on the north edge. This company later acquired holdings in Oklahoma, though it never quite attained production that would rate it among the top half-dozen producers in the field. The American Zinc, Lead & Smelting Co. first became an operator in 1924 on a 20-acre tract; although it soon acquired other tracts, its large expansion in the field did not come until considerably later. Tri-State Zinc, Inc., subsidiary of New Consolidated Gold Fields, Ltd., began drilling of leased tracts in 1926 and bought a developed mine in the following year. However, this company attained its prominence in the field in later years through its extensive operation of tailings mills.

No sharp division can be made between these large companies and the many experienced and efficient companies of moderate size which also expanded or consolidated and continued to dominate the field in point of numbers. Mature development of the mining field had so increased the producing acreage that in each of the peak years, 1925 and 1926, respectively 184 and 193 different companies shipped concentrates. Nearly three-fourths of these companies exceeded \$100,000 in gross annual income. In the 5 years from 1921 through 1925, the Picher field yielded 55 percent of the total zinc produced in the United States.

During the years of peak activity, a lead smelter was in operation at Hockerville, 3 miles east of Picher. It had been built in 1918 by the Ontario Smelting Co., and was sold in late 1923 to the Eagle Picher Lead Co. This company used it several years for the manufacture of antimonial lead. The plant was abandoned and dismantled in the early 1930's.

The 1920's marked the maturity of the field. Production generally declined in the latter half of the decade,

but the underlying cause was the sensitive adjustment to price, rather than depletion; in any year a greater output could have been made at the prevailing price if activities had not been curtailed to avoid overproduction. Nevertheless, a few mines were worked out by 1927, and the number of exhausted mines increased steadily from that time.

The latter half of the 1920's also witnessed the ascendance of the tailings mill as an important factor in total zinc production. Although recovery of zinc concentrates from rerun of tailings had been started as early as 1909 in the part of the field around Commerce, and had been carried on to some extent through the field as it was developed in all following years, the introduction of the flotation process in several of the mills during World War I had been followed by general adoption of this process in the mid-1920's, and remilling of the huge tailings piles that had accumulated when only jigging and tabling had been used was a next logical step. Figure 21 shows the percentage of the total zinc production of the field that has been recovered from tailings. In many operations only zinc was recovered, but some tailings mills also recovered a little lead. In general, as a far greater percentage of the lead than of the zinc had been recovered in the initial milling, little lead was left in the tailings. Use of the flotation process as an adjunct of jigging and tabling in the last half of the 1920's and in later years insured the recovery of 80-85 percent of the metal contained in the crude ore, compared to the 58-70 percent recovery estimated for the older milling. The amount of zinc recovered in the concentrates from the milling of old tailings varied in different years from 1.28 to 0.19 percent of the tailings tonnage treated, expressed as an annual average for the whole field. In the early years (through 1936) when most of the tailings were being retreated for the first time, the annual average grade was never lower than 0.71 percent. Like the grade of crude ore, the

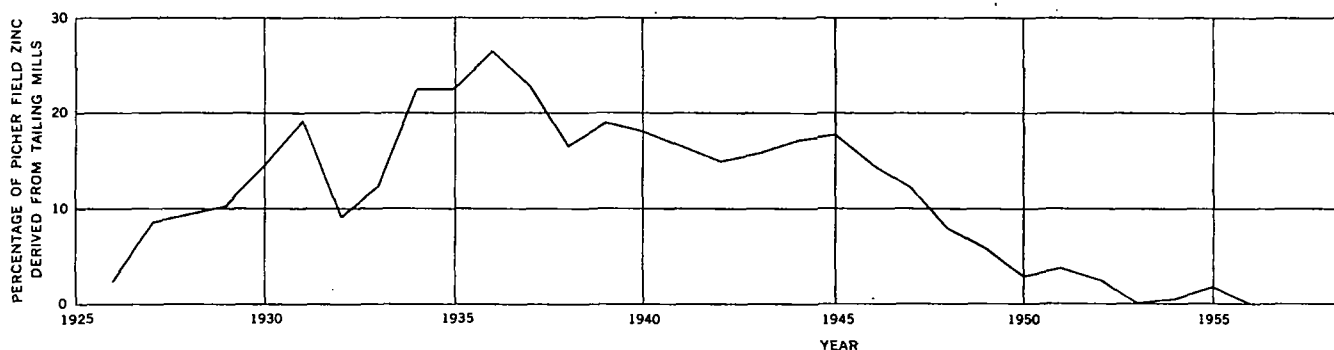


FIGURE 21.—Graph showing percentage of zinc production from reworking of tailings, Picher field (based on unpublished statistical data furnished by the U.S. Bureau of Mines). No production from tailings 1956-64.



grade of the tailings milled varied inversely with the price of zinc sulfide concentrates.

The zinc industry shared the economic doldrums of nearly all other industries during the depression of the early 1930's. Annual production dropped to a low of 168,000 tons of zinc concentrates in 1932, which was lower than any year since 1916. Pumping was discontinued in many mines, and the ground-water table, which had been kept below the level of mining by widespread pumping at many stations, was allowed to rise and partly fill some of the lower mine workings. By 1934, however, many of the mines had resumed operation, though with periods of inactivity to avoid overproduction, and most of the workings were pumped out. After the depth of the depression, the field showed a steady rise in production to 404,000 tons of zinc concentrates in 1937, and 430,000 tons in 1941, but this was only slightly more than half of the annual production for 1925. More and more mines were exhausted during the decade or were reduced to recovering the leaner blocks of ground, to cleaning up spots left in the earlier mining, or to salvaging pillars.

The 1930's also witnessed the growth of central milling in the field. The first mill built to treat ore from several tracts was the Bird Dog mill of the Commerce Mining & Royalty Co., completed in 1930. This plant was designed for operation at 2,750 tons capacity on a 24-hour basis, rather than the 10-hour basis common to mills up to that time (Isern, 1931). Haulage was by rail directly from the hoppers of the contributing mines. The success of this mill in sampling and milling ores from several different tracts indicated large economies in central milling over the practice that had prevailed up to that time (largely at the landowners' and royalty owners' insistence) of having separate mills on each 40- or 80-acre lease to insure proper royalty distribution. In 1932 the Eagle Picher Mining & Smelting Co., recently organized at that time to handle all mining-through-smelting activities of Eagle Picher Lead Co., completed a central mill near the southwest corner of the field, initially rated at 3,600 tons capacity but shortly thereafter stepped up to 5,500 tons. Other companies soon followed the example of hauling crude ore or tailings to a central company mill, though no other mills attained the size of operation of the Bird Dog and Eagle Picher mills, whose capacities were increased later in the decade, the latter to 10,000 tons. Many companies even abandoned milling altogether, and had their milling done on a custom basis by Eagle Picher or other companies. This procedure allowed more complete clean-up of depleted mines whose diminishing output was not sufficient to justify a milling operation. The central mills

were particularly efficient in recovering the values from the more refractory siliceous ores in which the sphalerite is finely disseminated; hence, a larger proportion of their product was a flotation concentrate.

In this period of lowering ore grade, rising costs, and trend toward centralized milling, elimination of the small operators was accelerated. Among the larger operators that expanded in relative importance by acquisition of other holdings, the Eagle Picher Mining & Smelting Co. was by far the leader. Early in 1931 this company took over by foreclosure the holdings of Canam Metals Corp., which had acquired enough producing properties 2 years earlier to make it for a short time the seventh largest producer in the field, only to succumb soon thereafter, a victim of the depression. Later in the same year, Eagle Picher absorbed the holdings of its rich subsidiary, the Consolidated Lead & Zinc Co.; and in 1937 it took over the assets of the Mary M. Mining Co., which in the meantime had grown to be fourth largest producer, in part through purchase of the Admiralty Zinc Co. and Black Eagle Mining Co. holdings in the preceding year. In 1938 the Eagle Picher Co. eclipsed its earlier accessions by purchasing the entire holdings and assets of the Commerce Mining & Royalty Co., which was at that time the next largest operator in the field and held large ore reserves. The technical and operating staffs of the two organizations were integrated to great advantage in the merger. In 1940 the company obtained, through an intermediary, the Barr mine, which had been the most productive property of the Vinegar Hill Zinc Co. Other acquisitions were made during the decade that, individually, were not so large as those mentioned, but in the aggregate amounted to a sizable expansion.

Most of the other companies previously mentioned that had been among the leaders in the 1920's remained strong and active during all or most of the decade between the depression and World War II, except that the Anna Beaver Mining Co. was sold in 1929 to the Commerce Mining & Royalty Co. In addition, the Rialto Mining Corp., an old producer in the field, became relatively more prominent in this period of falling production rates, even though its maximum annual output had been made during the preceding decade. Midcontinent Lead & Zinc Co. and the Davis-Big Chief Mining Co., both of which shipped their ore to the Eagle Picher central mill, were also among the leading producers.

An outstanding feature of the decade was the relatively large production from tailings. Of companies operating largely or entirely on tailings, Tri-State Zinc, Inc., Cardin Mining & Milling Co., Semple Mining Co., and Captain Milling Co., each was among the top 10

producers of the field for one or more of the years from 1936 to 1941. Many other companies also reworked tailings, including some of the largest that operated primarily on crude ore. The peak of production from tailings came in 1936 (fig. 21) when 104,500 tons of zinc sulfide concentrates, milled from this source, contained 26.5 percent of the zinc produced that year from the whole field.

The period of World War II was marked by a steady decline in rate of production, in spite of a nationwide system of subsidized premium prices for base metals that was designed to pay a profit to each marginal operator above his production costs. Perhaps the immediate cause of the decline was the general labor shortage, which not only hampered direct production but also hampered exploration and development that are the necessary prelude to production. The developed reserves were gradually depleted without new reserves being developed. In spite of continuation of the Premium Price Plan to mid-1947, the lag in new development prevented any immediate reversal in the downward trend of production. The average metal prices toward the end of the decade were in general high, but the fluctuations and uncertainties, particularly in zinc price, were not conducive to any pronounced upsurge in production rate. The zinc price drop in 1949 produced a new low in output that year, lower than any year since 1916.

Although the decline in production rate during World War II had immediate causes in labor and material shortages, these merely delayed the eventual decline brought on by progressive depletion. During the life of the field, new ore was constantly being found and developed by drilling, but this was mostly within the boundaries of the field as fairly well defined by the early 1920's. An extension of the main field in the Melrose, Kans., area was discovered by drilling in 1925, but it proved to be small, and was quickly mined out during 1944-49. In the early 1920's, a new source had been recognized in the low-grade sheet-ground deposits at a lower stratigraphic level (Grand Falls Chert Member of the Boone Formation) in the northeastern part of the field, near Baxter Springs. These deposits were first worked in the Hartley mine, and although similar deposits were mined in the same general area in most succeeding years, it was not until the late 1930's and especially the 1940's that the great surge of sheet-ground production was made. The main leader in this development was the St. Louis Smelting & Refining Co. which worked several tracts simultaneously, all tributary to their Ballard central mill. At the

same general time, a second large sheet-ground area was worked by Eagle Picher in the southwestern part of the field. Mining of these deeper deposits provided a temporary brake on the depletion rate, but they were not large in comparison to the original extent of mineralized ground in the field. The lean ore that had been passed up earlier was mined wherever it became economic, and conditions during the decade were especially favorable for this thus, the average grade of ore for 1946 was only 1.99 percent of combined zinc and lead as recovered in the concentrates (table 5).

A technologic development that contributed greatly to the economic recovery of progressively lower grade ores was the increasing mechanization of mining during and following World War II. The manpower shortage that had arisen made mechanization a necessity, but it proved to be a blessing in disguise, for the resultant economies delayed still further the final exhaustion of the field. Introduction of slushers in sheet-ground mines in the late 1930's and of track-mounted shovels in the early part of the war largely did away with the traditional method of hand shoveling the ore into steel cans at the working face. Rubber-tired diesel trucks of 10-ton capacity were perfected for underground haulage, starting in 1946, and within 3 years, 25 of these trucks were in steady operation by the Eagle Picher Co., in combination with diesel Caterpillar loading equipment (Clarke, 1949). Other companies quickly adopted the same methods. Trackless loaders and haulage give a greater flexibility to underground mining during cleanup operations in that scattered spots of ore can be quickly and economically mined in extensively cut ground, whereas the laying of track to each spot under the older system of electric train or tail-rope track haulage and track-mounted shovels would be impractical. Commonly, what appeared to be a small spot of ore would lead into an unsuspected block of considerable size that could not have been recovered under other conditions.

The tailings available for retreatment were likewise depleted. During the war the "primary" tailings were exhausted, and there was a definite transition to second run and even third run of some of the tailings. The lowest average annual recovery of 0.19 grade percent zinc from tailings was reached in 1946.

In the period since 1940, the Eagle Picher Co. has dominated in the production from the field, usually producing two to six times the output of its nearest competitor. Its central mill was expanded to a capacity of 15,000 tons per day, though part of this capacity is for custom ore. Other leading companies have included

the St. Louis Smelting & Refining Co. (after 1948 recorded as a division of the National Lead Co.), Federal Mining & Smelting Co., Davis-Big Chief Mining Co. (which in 1941 acquired the mines of Skelton Lead & Zinc Co.), Rialto Mining Corp., Evans Wallower Zinc, Inc., Tri-State Zinc, Inc. (tailings), and Cardin Mining & Milling Co. (tailings). After the Federal central mill (Gordon mill) burned in 1943, most of its ore was milled on a custom basis by the Eagle Picher Co. until the Federal company abandoned the field 10 years later. In 1948 the Nellie B. Mining Co., new in the field, acquired extensive holdings largely in a block east and southeast of Cardin, including the remaining assets of Evans Wallower Zinc, Inc., those of Rialto Mining Corp., and from the Marcia K. Mining Co., the properties that a few weeks earlier had belonged to the Davis-Big Chief Mining Co., as well as additional properties of the Marcia K. Mining Co. In 1951 the American Zinc Lead & Smelting Co. bought out the Nellie B. Mining Co. to become the second largest producer in the field.

Because of depressed metal markets, many operations were cut back or suspended in 1957, and by midyear of 1958, all the major mining operations were closed in the most complete shutdown of the field's history. The National Lead Co. dismantled and removed its central (Ballard) mill in 1959; its mining equipment, facilities, and most of its leases were acquired by the Eagle Picher Co.

Mining was resumed at a reduced rate in 1960 and has gradually increased, though (as of 1964) it has not reached the status that prevailed before the 1957 curtailment.

As of 1964, many properties have been worked out and abandoned, and others are reaching this stage one at a time. The bulk of the remaining reserves in the field are marginal in grade and can be mined only so long as economic conditions remain favorable. Because the Eagle Picher Co. has integrated activities in the zinc and lead industry that include smelting and refining as well as fabrication and marketing of final products, this company may be able to mine and mill lower grade ore than a company that makes its entire profit on the concentrates sold. Hence, it may be expected that this company will gradually acquire such properties as are abandoned by the other companies if any marginal reserves remain. Any economic recession that could lead to the abandonment of pumping in the field for any time, as in 1930, would probably result in loss of the remaining low-grade reserves, for the mine workings are so extensive and so interconnected that the cost of

pumping them out again would be prohibitive when balanced against the tonnage and grade of the remaining reserves.

### MINERALOGY OF THE ORES

Sphalerite and galena are the commercial ore minerals. They are accompanied by a little chalcopyrite and enargite but in amounts so small that the contained copper is not recovered. Marcasite and pyrite are common associates of the ore minerals, though the pyrite is usually in such small grains and so sparse that its effect in the ore is negligible. Wurtzite was not found in the Picher field but is present at one mine near Joplin. Gangue minerals include jasperoid, dolomite, calcite, and locally, a little quartz or barite. In the early days of mining in the Lincolnville area southeast of Quapaw, some smithsonite and calamine were marketed from surficial deposits, but these minerals are no longer of more than accidental occurrence in the field. The galena locally has alteration rims of anglesite, some of which, in the deeper mines of the western part of the field, formed after the ground was opened by mining. Sulfates of calcium, iron, zinc, and magnesium, also formed after mining began, are common as efflorescences in some of the mine workings but are insignificant in actual bulk. Although neither a primary nor secondary gangue material in the strict sense, a thick black petroleum or light tar that originally had been trapped on top of the ground water in the structural highs beneath the impervious shale cover has seeped down upon removal of the mine water and permeates the ore-bearing ground or floats on the underground sumps in many places (Fowler, 1933).

In its major features the mineralogy of the Picher field does not differ greatly from that prevailing in the rest of the Tri-State region. There may be some minor differences between Picher and Joplin in the crystal form assumed by sphalerite, which are mentioned below. The Joplin area contains at least one deposit which is unique, in comparison to other Tri-State deposits, in composition and form of its zinc sulfide. This deposit is in the Zig Zag mine which was being worked in the mid-1930's. To present a more nearly complete account of Tri-State mineralogy, and particularly since the type of mineralization may have genetic significance, the mineralogy of the Zig Zag mine is discussed in this report.

In the following discussion the minerals are divided into primary minerals and secondary minerals. In the primary mineral group, the sulfides are treated before the gangue minerals.

